WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: New Approach for Assessing Regional Groundwater Vulnerability to Contamination

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Statement of critical regional or state water problem

A large portion of California's groundwater supply, which furnishes nearly half of domestic, urban, and agricultural water in the State, is vulnerable to degradation by pollutants originating from point- and non-point sources. Results of recent research (Fogg et al., 1995; Fogg and LaBolle, 1995) on regional-scale contaminant transport in a typical alluvial basin in California and trends in shallow groundwater quality (e.g., Anton et al., 1988; Frantz, 1994; Snow, 1988) strongly suggest there is real potential for groundwater quality in many basins to grow progressively worse well into the next century. Scientifically defensible policies for managing groundwater quality will not occur until (1) the long-term (decades to centuries) sustainability of groundwater quality in the presence of nonpoint-sources of contamination is better understood, (2) the cause-and-effect relationships between certain land management practices and basin-scale water quality is better defined, and (3) better tools become available for characterizing the vulnerability of aquifers to contamination as a function of space and time. The current lack of such knowledge and tools leads to divergent water quality management policies that are either too restrictive or too relaxed.

The work proposed herein would develop and test a new approach for characterizing aquifer vulnerability while elucidating the cause-and-effect relationships between land management practices and groundwater quality in an alluvial fan setting typical of the east side of the San Joaquin Valley. The hydrologic methods to be used are innovations by themselves, but the main contributions of this work will be the development and validation of an overall approach and the increased insight into long-term sustainability of groundwater quality in groundwater basins containing nonpoint sources. We anticipate this work will stimulate a rethinking of groundwater quality management policy.

Statement of results or benefits

The chief results will be (1) development and refinement of a saturated-zone approach for assessing groundwater vulnerability to contamination by nonpoint-source contamination, (2) better understanding of the transient response of regional water quality in a typical alluvial aquifer system to nonpoint-source contamination, and (3) development of a methodology for characterizing heterogeneity of alluvial fan aquifers, which comprise most of the major aquifers in California and the Western U.S., with unprecedented realism using commonly available data. Additional benefits will include development of subsurface characterization and models of the Kings River fan aquifer system that will help (1) forecast possible future changes in DBCP concentrations and possible regional remediation strategies using existing pumping wells, (2) represent groundwater flow patterns more accurately, and (3) lead to policy developments that more effectively manage and protect groundwater quality in the system. Ultimately, we hope that this work will lead to "paradigm-shifts" in how California views long-term sustainability of groundwater quality, methods for characterizing the groundwater systems, and, in turn, the future path for evolution of groundwater management policies.

The proposed work addresses the following research needs listed in the National Research Council's cogent summary of the state-of-the-art in groundwater vulnerability assessment (NRC, 1993):

Develop a better understanding of all processes that affect the transport and fate of contaminants.

o Develop improved approaches to obtaining information on the residence time of water along flow paths and identifying recharge and discharge areas.

o Develop unified ways to combine soils and geologic information in vulnerability assessments.

o Develop methods for merging data obtained at different spatial and temporal scales into a common scale for vulnerability assessment. "

o Obtain more information on the uncertainty associated with vulnerability assessments and develop ways to display this uncertainty.

Nature, scope, and objectives of the research

Groundwater accounts for nearly half of urban and agricultural water supply in California and is an increasingly vital source of water. Much of the groundwater, however, is vulnerable to degradation by pollutants originating from point- and non-point sources.

Nonpoint-source examples include nitrate contamination in the Salinas Valley (Snow et al., 1988) and DBCP contamination in the San Joaquin Valley (Domagalski and Dubrovsky, 1991; Frantz, 1994). Transport analyses by Fogg et al. (1995) and Fogg and LaBolle (1995) suggest that because of the significant time lag (decades) between introduction of contaminants at the surface and their appearance at the well screen, the current trends are symptomatic of a larger trend in which groundwater quality may continue to worsen for several more decades or even centuries. This raises the question: "Is our groundwater quality sustainable under current practices, and what policies are needed to ensure sustainable groundwater quality into the next century?" In order to make informed decisions on future and current land management practices, characterization of groundwater vulnerability and sensitivity to contamination from surface land use must be improved.

Regional groundwater quality protection is a growing area of research at the interface between hydrogeology and water resources policy and is typically described with the terms "vulnerability" and "sensitivity. " Sensitivity refers to the risk of groundwater contamination as a function of the intrinsic characteristics of the subsurface, irrespective of well pumping or source types, locations and strengths at the surface (EPA, 1993). Vulnerability includes sensitivity and nature of the sources (NRC, 1993). The goal of vulnerability assessment is to provide policy makers with a map of regions most susceptible to contamination and an indication of time involved in contaminant transport so that land management practices can be optimized to protect the groundwater resource. The spatially dependent vulnerability of a groundwater basin to contamination is seldom known with much certainty. Consequently, working strategies for prevention of groundwater contamination are rare, particularly for nonpoint-source problems.

In addition to the need for understanding travel times and contaminant pathways, the NRC (1993) notes that "uncertainty is inherent in all vulnerability assessments." In order to make informed decisions on land management, policy makers must be provided with a clear understanding of the uncertainty of a vulnerability assessment (NRC, 1993). Few published assessments account for uncertainties from either model or data errors (NRC, 1993).

Clearly, policies to successfully manage regional groundwater quality are not possible without an understanding of pollutant transport rates and pathways between the sources and well screens. In theory, this would allow one to map those regions of the groundwater system that are most vulnerable or sensitive to contamination. Past approaches all rely predominantly on near-surface information such as soil types, land use, and vadose-zone processes to assess vulnerability. Success of these techniques has been rather disappointing either because the mapped surficial attributes only weakly correlate with actual vulnerability, the vadose zone processes cannot be modeled in adequate detail, or the methods do not account for the significant changes that can occur in contaminant concentrations below the water table en route to well screens. Because the contaminants typically reside in the saturated zone during most of their history from the time of introduction at the land surface to their appearance in water wells, an approach that focuses on saturated zone characterization will improve aquifer vulnerability assessment.

With new approaches for both characterizing the system heterogeneity and backward-time modeling of transport in aquifer systems, transport processes in the saturated zone can commonly be predicted with greater certainty than processes in the vadose zone. Furthermore, we propose and partially demonstrate a methodology herein that, when combined with the more traditional, shallow assessment techniques being used currently, will provide a leap forward in our ability to quantitatively map vulnerability or sensitivity of groundwater systems to contamination. The method also provides needed information on the timing and uncertainty of the contaminant effects, which are essential for formulation of successful management policy.

The study area for this work is the Kings River alluvial fan aquifer system, located southeast of Fresno, California. The system, which consists of a complex distribution of gravel, sand, silt, and clay, is typical of the many aquifer alluvial depositional systems along the east side of the Central Valley. The Kings River aquifer system has an interesting history of groundwater contamination from 1,2-dibromo-3-chloropropane (DBCP). DBCP was a widely-used nematicide during the 1950's through the 1970's, until it was banned in California in 1979 for potential carcinogenic and sterility risks to the production workers in chemical plants and agricultural workers in the fields were it was applied (Frantz, 1994). During and since the 1970's, the contaminant has been detected in thousands of water wells (Domagalski and Dubrovsky, 1991; Frantz, 1994), resulting in perhaps the most serious nonpoint-source pesticide contamination problem in California groundwater. Municipalities have been forced to drill to deeper groundwater resources and land use managers have been left with attempting to develop means of protecting the groundwater resource. The complexity of this system has been a hindrance to understanding the complex nature of aquifer vulnerability and in determining travel time estimates and contaminant pathways in the Fresno region.

Detailed information on existing and historical concentrations of DBCP in groundwater (Frantz, 1994), high-quality soil mapping, continuous core data from stratigraphic test wells, pumping test results for hydraulic conductivity estimates, relatively high quality well-log data, and historic and current land-use mapping make the Kings River alluvial fan an excellent candidate for developing and testing the new approach for assessing groundwater vulnerability. Additionally, the U.S. Geological Survey has age-dated groundwater at several locations in the area using the relatively reliable CFC method. There is a high probability that these age-date data will become available for use in calibration of the flow and transport models that will be developed during this two-year study.